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(54) **EXHAUST PURIFYING SYSTEM FOR INTERNAL COMBUSTION ENGINE**

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See application file for complete search history.

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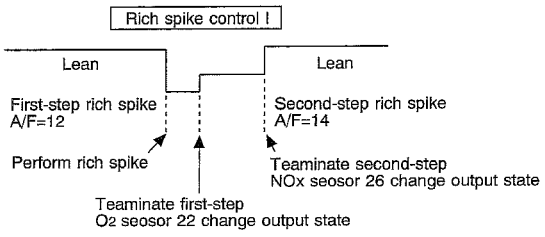
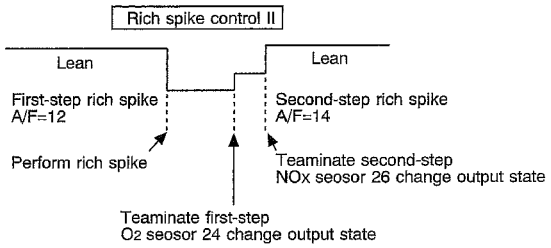
(57) **ABSTRACT**

An object is to provide an exhaust purifying system for an internal combustion engine having an NSR catalyst, which can inhibit emissions from being aggravated by blow-by of NOx. An exhaust purifying system for an internal combustion engine capable of a lean burn operation is provided. The exhaust purifying system includes: an NSR catalyst disposed in an exhaust passage of the internal combustion engine; an SCR disposed downstream of the NSR catalyst; a NOx sensor disposed downstream of the SCR, the NOx sensor producing an output according to an NH_3 concentration; and rich spike means for performing a rich spike. The rich spike means starts the rich spike at a predetermined timing during a lean burn operation and terminates the rich spike at a timing when the NOx sensor issues a predetermined output characteristic indicative of a rise in the NH_3 concentration.

8 Claims, 9 Drawing Sheets





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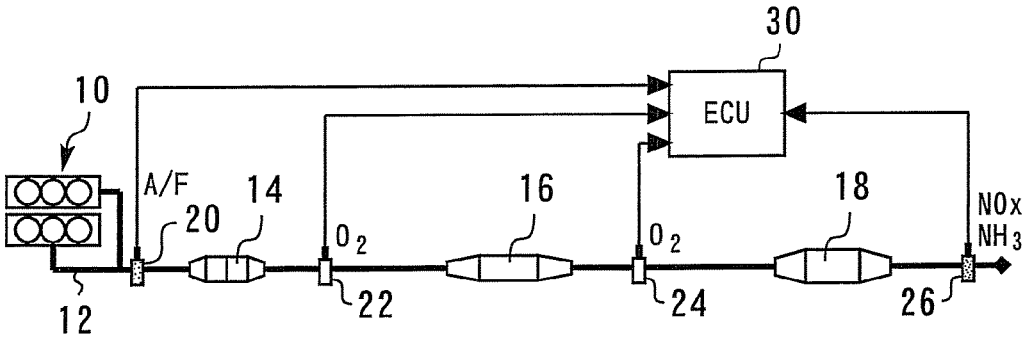
30
ECU
10
A/F
20
14
16
18
NOx
NH3
O2
O2
12
22
24
26

Fig. 1

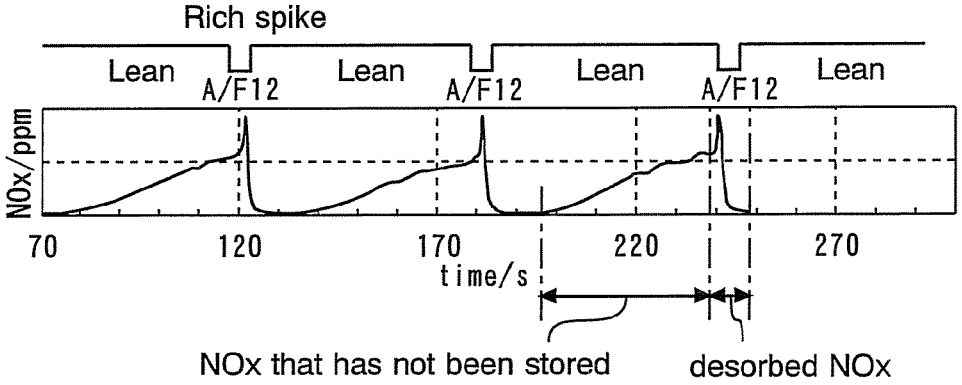
Rich spike
Lean
A/F12
Lean
A/F12
Lean
A/F12
Lean
NOx/ppm
70
120
170
220
270
time/s
NOx that has not been stored
desorbed NOx

Fig. 2

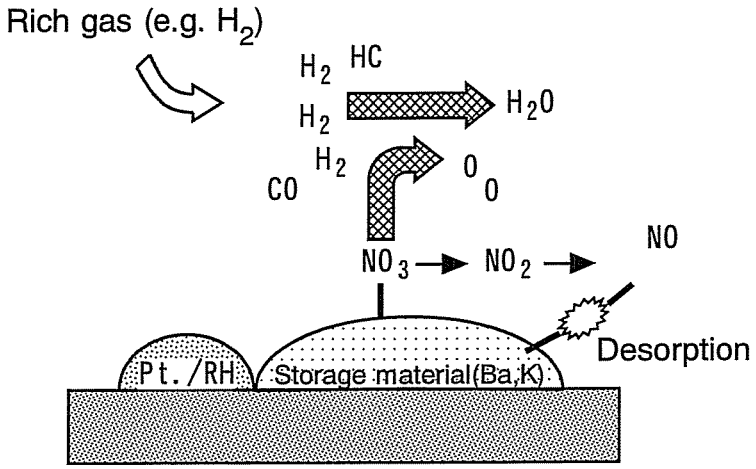
Rich gas (e.g. H_2)
H_2 HC
H_2
H_2O
CO H_2
O
O
NO
NO_3
NO_2
Desorption
Pt./RH
Storage material(Ba,K)

Fig. 3

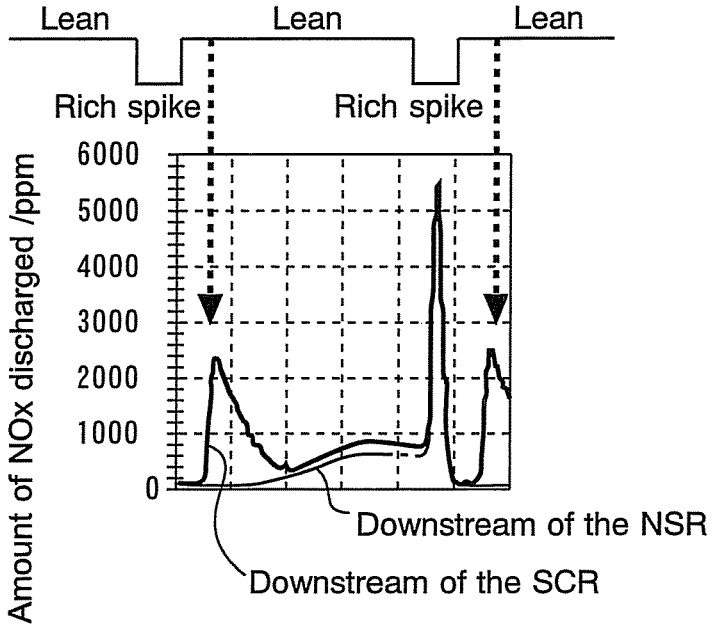
Lean
Lean
Lean
Rich spike
Rich spike
6000
5000
4000
3000
2000
1000
0
Amount of NOx discharged /ppm
Downstream of the NSR
Downstream of the SCR

Fig. 4

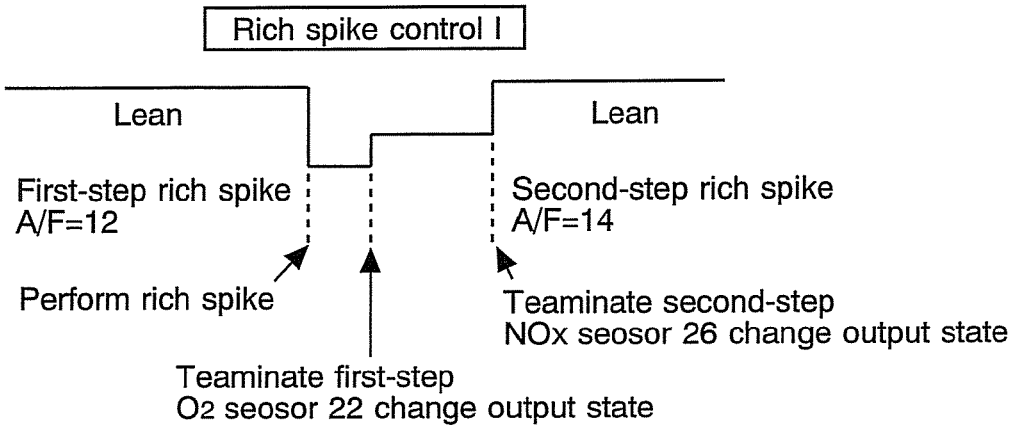
Rich spike control I
Lean
Lean
First-step rich spike
A/F=12
Second-step rich spike
A/F=14
Perform rich spike
Teaminate second-step
NOx seosor 26 change output state
Teaminate first-step
O2 seosor 22 change output state

Fig. 5(A)

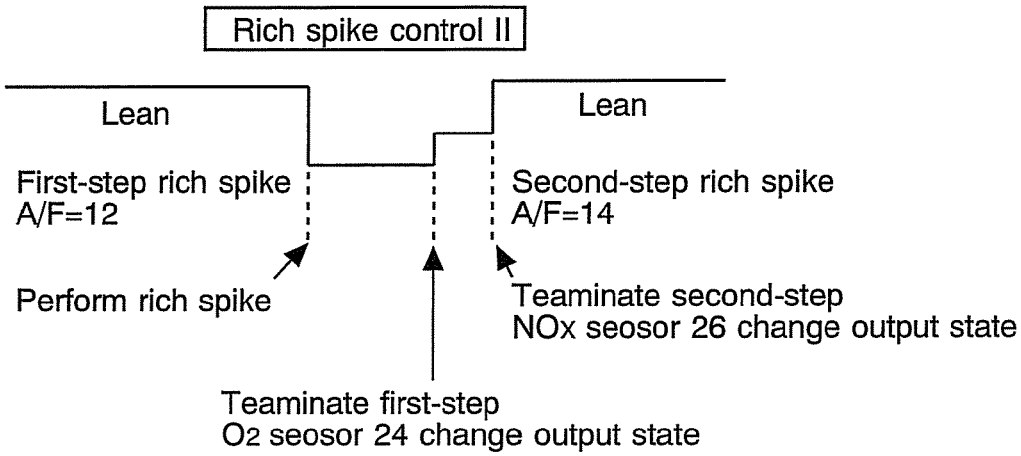
Rich spike control II
Lean
Lean
First-step rich spike
A/F=12
Second-step rich spike
A/F=14
Perform rich spike
Teaminate second-step
NOx seosor 26 change output state
Teaminate first-step
O2 seosor 24 change output state

Fig. 5(B)

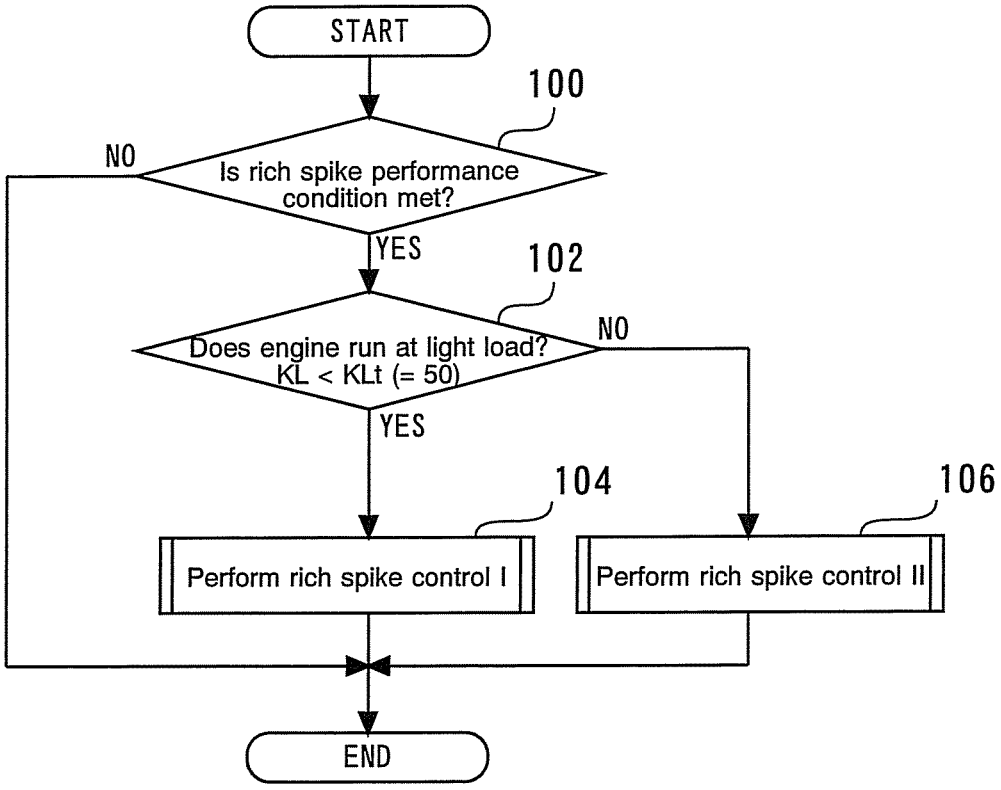
START
100
Is rich spike performance condition met?
NO
YES
102
Does engine run at light load? KL < KLt (= 50)
NO
YES
104
Perform rich spike control I
106
Perform rich spike control II
END

Fig. 6

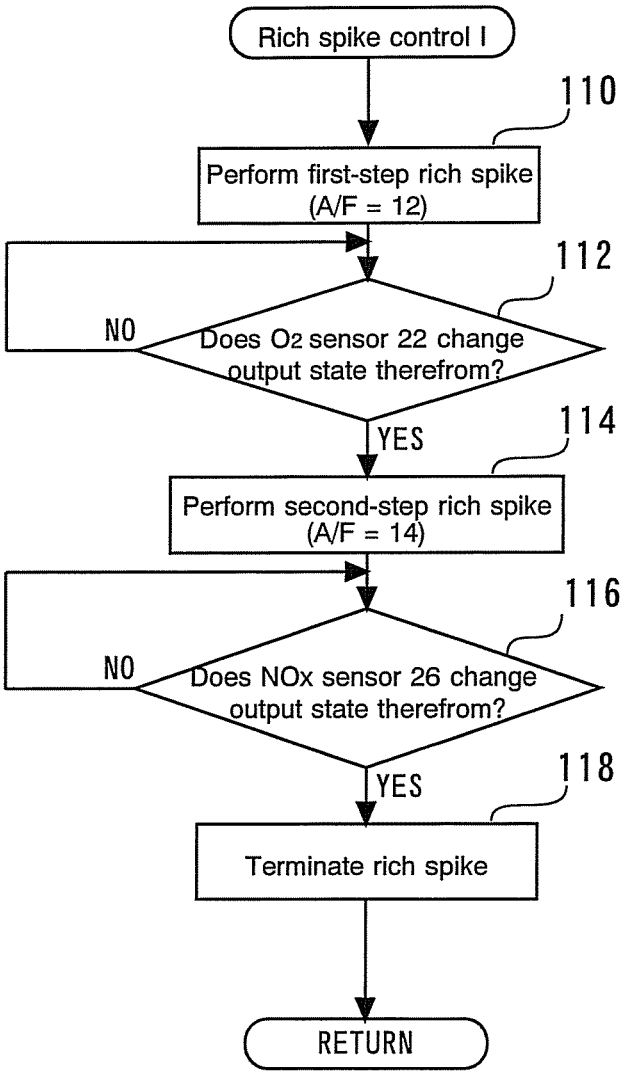
Rich spike control I
110
Perform first-step rich spike
(A/F = 12)
112
NO
Does O2 sensor 22 change
output state therefrom?
YES
114
Perform second-step rich spike
(A/F = 14)
116
NO
Does NOx sensor 26 change
output state therefrom?
YES
118
Terminate rich spike
RETURN

Fig. 7

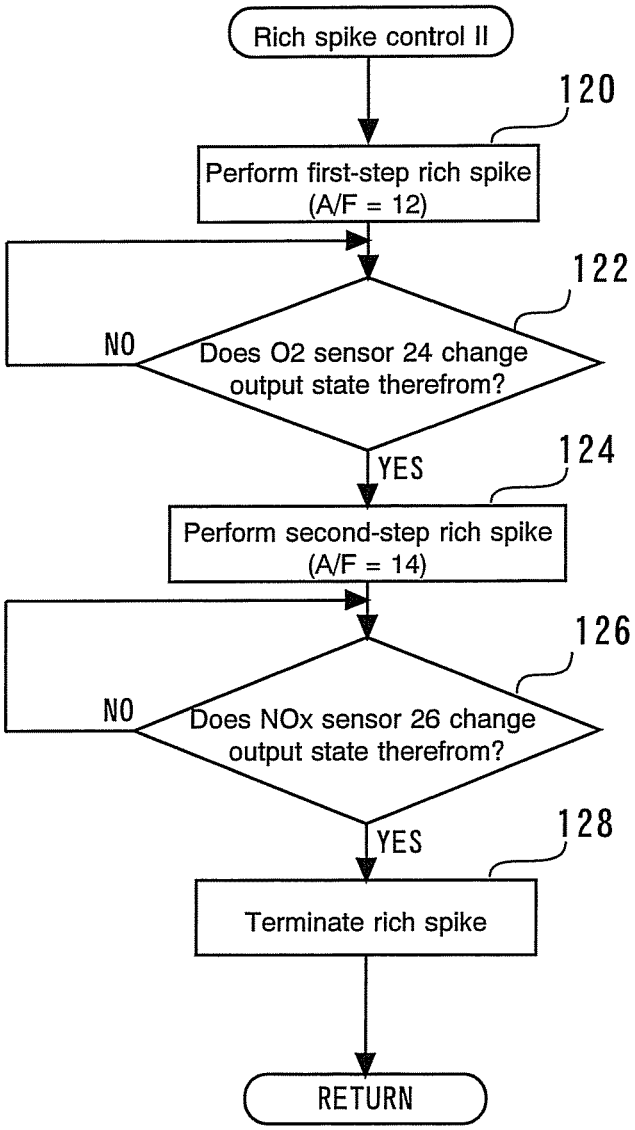
Rich spike control II
120
Perform first-step rich spike
(A/F = 12)
122
NO
Does O2 sensor 24 change
output state therefrom?
YES
124
Perform second-step rich spike
(A/F = 14)
126
NO
Does NOx sensor 26 change
output state therefrom?
YES
128
Terminate rich spike
RETURN

Fig. 8

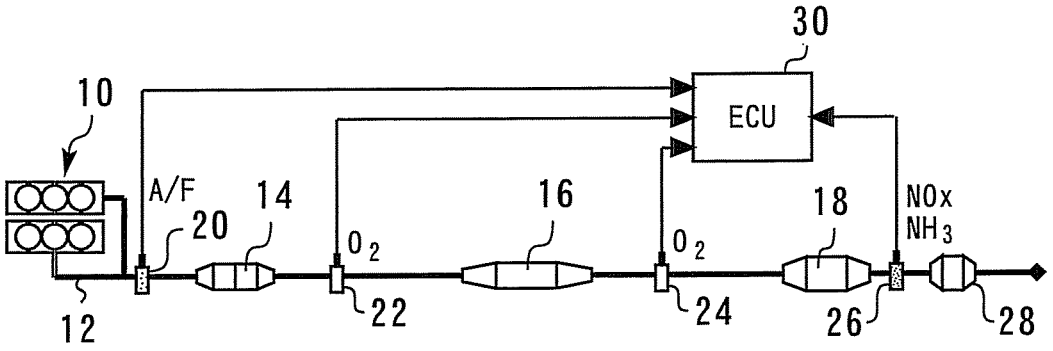
30
ECU
10
A/F
20
14
16
18
NOx
NH3
O2
O2
12
22
24
26
28

Fig. 9

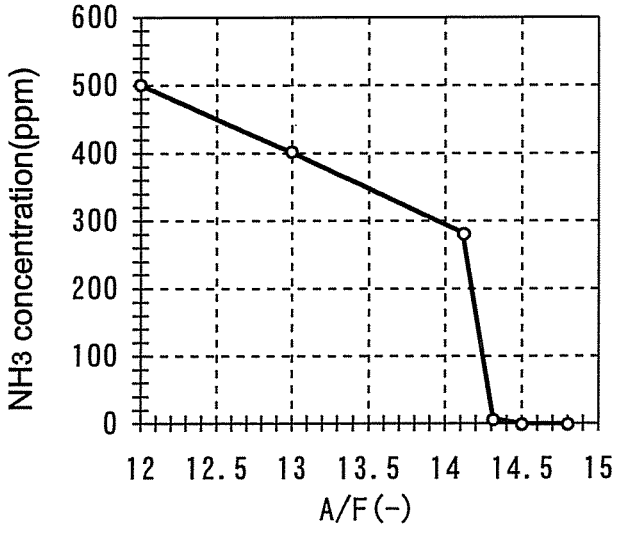
600
500
400
300
200
100
0
NH3 concentration(ppm)
12
12.5
13
13.5
14
14.5
15
A/F (-)

Fig. 10

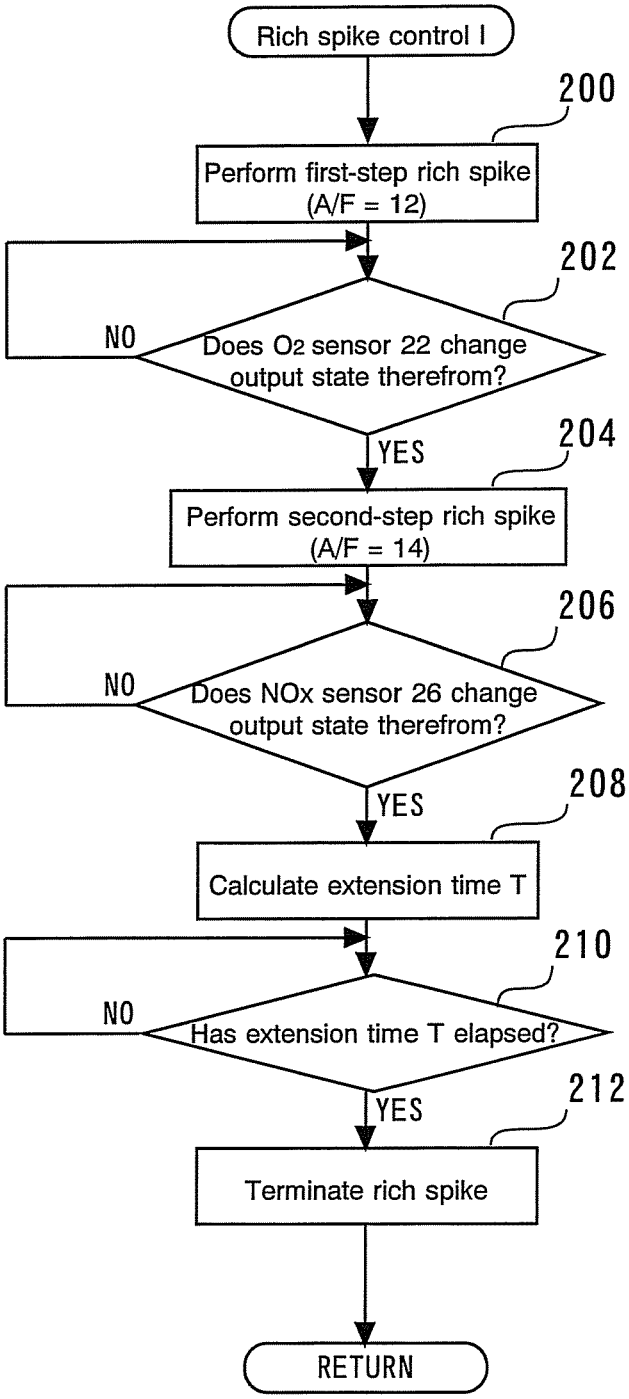
Rich spike control I
200
Perform first-step rich spike (A/F = 12)
202
NO
Does O2 sensor 22 change output state therefrom?
YES
204
Perform second-step rich spike (A/F = 14)
206
NO
Does NOx sensor 26 change output state therefrom?
YES
208
Calculate extension time T
210
NO
Has extension time T elapsed?
YES
212
Terminate rich spike
RETURN

Fig. 11

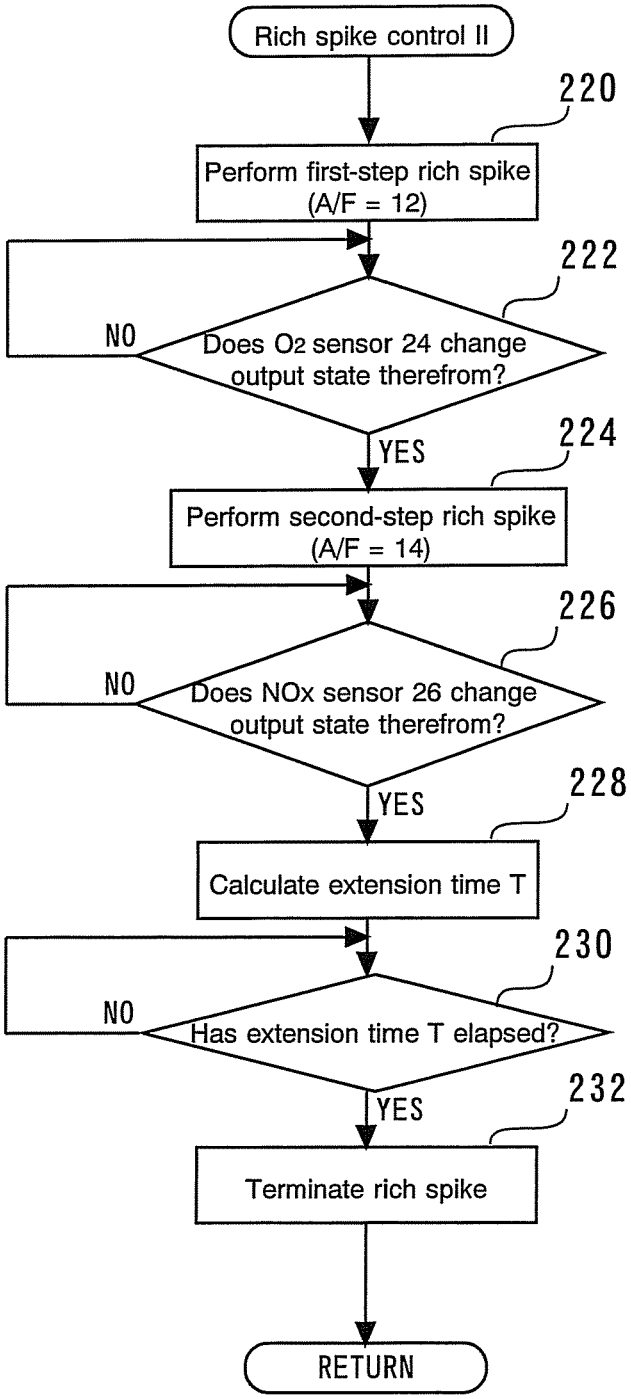
Rich spike control II
220
Perform first-step rich spike (A/F = 12)
222
NO
Does O2 sensor 24 change output state therefrom?
YES
224
Perform second-step rich spike (A/F = 14)
226
NO
Does NOx sensor 26 change output state therefrom?
YES
228
Calculate extension time T
230
NO
Has extension time T elapsed?
YES
232
Terminate rich spike
RETURN

Fig. 12

EXHAUST PURIFYING SYSTEM FOR INTERNAL COMBUSTION ENGINE

This is a 371 national phase application of PCT/JP2009/067422 filed 6 Oct. 2009, the content of which is incorporated herein by reference.

TECHNICAL FIELD

The present invention relates, in general, to exhaust purifying systems for internal combustion engines and, in particular, to an exhaust purifying system for an internal combustion engine performing a rich spike control that temporarily makes an air-fuel ratio rich in order to purify NOx stored in a NOx storage-reduction catalyst.

BACKGROUND ART

There has been known a system that includes a NOx storage-reduction catalyst (hereinafter referred to as an "NSR catalyst") disposed in an exhaust passage of an internal combustion engine as disclosed in, for example, JP-A-2001-271679. The NSR catalyst has a storage function of internally storing nitrogen oxide (NOx) contained in a burned gas discharged from the internal combustion engine and a catalyst function of purifying, for example, NOx and hydrocarbon (HC). When the internal combustion engine is operated at a lean air-fuel ratio, an exhaust gas containing a large amount of NOx is discharged. The NSR catalyst therefore stores the NOx internally to inhibit the same from being released to a downstream side of the catalyst.

The NOx stored in the NSR catalyst is purified at a predetermined timing. More specifically, the above conventional art system performs rich spike that temporarily discharges an unburned component from the internal combustion engine. The NOx of the catalyst is thereby reacted with the unburned component in the catalyst.

When a large amount of unburned component is discharged from the internal combustion engine as a result of the initiation of the rich spike, the exhaust gas released to the downstream side of the NSR catalyst is a stoichiometric environment as long as NOx to be reduced by the unburned component is left in the catalyst. When reduction of NOx stored in the catalyst is thereafter completed, the unburned component is released downstream of the catalyst, so that the exhaust gas changes to a rich environment. The above conventional art system is adapted to detect such a change of the exhaust gas downstream of the catalyst to the rich environment, from oxygen concentration or nitrogen oxide concentration and, at the detecting timing, terminate the rich spike. This prevents performance of excessive rich spike, so that fuel efficiency can be prevented from being aggravated.

Patent Document 1: JP-A-2001-271679
Patent Document 2: JP-A-2000-356125

DISCLOSURE OF INVENTION

Problems to be Solved by the Invention

The above-described conventional art system processes NOx stored in the NSR catalyst by rich spike. Performance of the rich spike may, however, involve release of part of the stored NOx downstream of the catalyst. Specifically, when the unburned component as a reducing agent is introduced to the NSR catalyst as a result of the performance of the rich spike, the stored NOx is desorbed and reacted on the catalyst. Part of the desorbed NOx, however, leaks downstream of the catalyst without being purified on the catalyst. A possible method for inhibiting this blow-by of NOx is to increase catalyst capacity to thereby increase a reaction field; however, the increased capacity of the catalyst invites a considerable increase in cost as a result of the increase in noble metal. There is therefore a need for a system that can inhibit emissions from being aggravated by the blow-by of NOx without having to increase the catalyst capacity.

The present invention has been made to solve the foregoing problem and it is an object of the present invention to provide an exhaust purifying system for an internal combustion engine having an NSR catalyst that can inhibit emissions from being aggravated by blow-by of NOx.

Means for Solving the Problems

To achieve the foregoing object, a first aspect of the present invention provides an exhaust purifying system for an internal combustion engine capable of a lean burn operation. The exhaust purifying system is characterized by including: an NOx storage-reduction catalyst (hereinafter referred to as an "NSR catalyst") disposed in an exhaust passage of the internal combustion engine; an NOx selective catalytic reduction (hereinafter referred to as an "SCR") disposed downstream of the NSR catalyst; an exhaust gas sensor disposed downstream of the SCR, the exhaust gas sensor producing an output according to an NH_3 concentration; and rich spike means for performing a rich spike. The exhaust purifying system is characterized in that the rich spike means starts the rich spike at a predetermined timing during a lean burn operation and terminates the rich spike at a timing when the exhaust gas sensor issues a predetermined output characteristic indicative of a rise in the NH_3 concentration.

The exhaust purifying system for an internal combustion engine according to a second aspect of the present invention is characterized, in the first aspect of the present invention, by further comprising: a three-way catalyst disposed upstream of the NSR catalyst; and a second exhaust gas sensor disposed upstream of the NSR catalyst and downstream of the three-way catalyst, the second exhaust gas sensor producing an output according to an oxygen concentration. The exhaust purifying system is characterized in that: the rich spike means includes: first rich spike means for performing a rich spike at a predetermined air-fuel ratio; second rich spike means for performing a rich spike at an air-fuel ratio leaner than the predetermined air-fuel ratio; and switchover means for switching operation mode from the first rich spike means to the second rich spike means at a timing when the second exhaust gas sensor issues a predetermined output characteristic indicative of a reduction in the oxygen concentration when the internal combustion engine runs at light load.

The exhaust purifying system for an internal combustion engine according to a third aspect of the present invention is characterized, in the first aspect of the present invention, by further comprising: a third exhaust gas sensor disposed downstream of the NSR catalyst and upstream of the SCR, the third exhaust gas sensor producing an output according to the oxygen concentration. The exhaust purifying system is characterized in that the rich spike means includes: first rich spike means for performing a rich spike at a predetermined air-fuel ratio; second rich spike means for performing a rich spike at an air-fuel ratio leaner than the predetermined air-fuel ratio; and second switchover means for switching operation mode from the first rich spike means to the second rich spike means at a timing when the third exhaust gas sensor issues a prede-

termined output characteristic indicative of a reduction in the oxygen concentration when the internal combustion engine runs at heavy load.

The exhaust purifying system for an internal combustion engine according to a fourth aspect of the present invention is characterized, in any one of the first to third aspects of the present invention, in that the SCR is an Fe-based zeolite catalyst.

The exhaust purifying system for an internal combustion engine according to a fifth aspect of the present invention is characterized, in any one of the first to fourth aspects of the present invention, by further comprising a second NOx selective catalytic reduction (hereinafter referred to as a "second SCR") disposed downstream of the exhaust gas sensor.

The exhaust purifying system for an internal combustion engine according to a sixth aspect of the present invention is characterized, in the fifth aspect of the present invention, in that the second SCR is an Fe-based zeolite catalyst.

To achieve the foregoing object, a seventh aspect of the present invention provides an exhaust purifying system for an internal combustion engine capable of a lean burn operation. The exhaust purifying system is characterized by including: an NOx storage-reduction catalyst (hereinafter referred to as an "NSR catalyst") disposed in an exhaust passage of the internal combustion engine; an NOx selective catalytic reduction (hereinafter referred to as an "SCR") disposed downstream of the NSR catalyst; a second NOx selective catalytic reduction (hereinafter referred to as a "second SCR") disposed downstream of the SCR; rich spike means for performing a rich spike; and estimating means for estimating an amount of NH_3 stored in the second SCR while the rich spike is performed. The exhaust purifying system is characterized in that the rich spike means starts the rich spike at a predetermined timing during a lean burn operation and terminates the rich spike at a timing when the amount of NH_3 estimated by the estimating means reaches a predetermined amount.

The exhaust purifying system for an internal combustion engine according to an eighth aspect of the present invention is characterized, in the seventh aspect of the present invention, in that the SCR and the second SCR are Fe-based zeolite catalysts.

Effects of the Invention

When the rich spike is performed, NH_3 is produced in the NSR catalyst (NOx storage-reduction catalyst). The produced NH_3 is circulated through the exhaust passage and stored in the NOx selective catalytic reduction (SCR) disposed on the downstream side. The SCR selectively reduces NOx that has leaked downstream of the NSR catalyst by using the NH_3 stored therein. In the first aspect of the present invention, the rich spike is terminated at the timing when the exhaust gas sensor issues a predetermined output characteristic signal indicative of a rise in the NH_3 concentration, specifically, at the timing of blow-by of NH_3 downstream of the SCR. The blow-by of NH_3 means that the SCR has stored NH_3 to the full capacity thereof. By terminating the rich spike at such timing in this aspect of the present invention, therefore, a situation in which the rich spike is excessively performed to aggravate emissions or fuel efficiency can be effectively avoided, while a maximum amount of NH_3 can be stored in the SCR.

In the second aspect of the present invention, the first rich spike means is switched to the second rich spike means in which an air-fuel ratio is leaner than that of the first rich spike means at the timing when the second exhaust gas sensor issues a predetermined output characteristic signal indicative of reduction in the oxygen concentration when the internal combustion engine runs at light load, specifically, at the timing when the air-fuel ratio on the upstream side of the NSR catalyst is a predetermined rich air-fuel ratio. When the internal combustion engine runs at light load, a relatively small amount of NOx is discharged. This reduces the necessity of producing a large amount of NH_3 for storage in the SCR. Consequently, in this aspect of the present invention, NH_3 can be stored in the SCR, while aggravation of HC and CO emissions or fuel efficiency is preferentially inhibited.

In the third aspect of the present invention, the first rich spike means is switched to the second rich spike means in which an air-fuel ratio is leaner than that of the first rich spike means at the timing when the third exhaust gas sensor issues a predetermined output characteristic signal indicative of reduction in the oxygen concentration when the internal combustion engine runs at heavy load, specifically, at the timing when the air-fuel ratio on the downstream side of the NSR catalyst is a predetermined rich air-fuel ratio. When the internal combustion engine runs at heavy load, a relatively large amount of NOx is discharged. This increases the necessity of producing a large amount of NH_3 for storage in the SCR. Further, the amount of NH_3 produced in the NSR catalyst is greater in the rich spike with a rich air-fuel ratio. Consequently, in this aspect of the present invention, aggravation of HC and CO emissions or fuel efficiency can be inhibited, while NH_3 is preferentially stored in the SCR.

In the fourth aspect of the present invention, the Fe-based zeolite is used for the SCR. Consequently, in this aspect of the present invention, the NOx selective reduction performance in the SCR can be effectively enhanced.

Even if the rich spike is terminated at the timing when the exhaust gas sensor issues the predetermined output characteristic signal indicative of a rise in the oxygen concentration, NH_3 that represents a portion of transport lag is released downstream of the SCR. In the fifth aspect of the present invention, the second SCR is disposed downstream of the exhaust gas sensor. Consequently, in this aspect of the present invention, the NH_3 representing the transport lag portion can be stored in the second SCR, so that aggravation of NH_3 emissions can be effectively inhibited.

In the sixth aspect of the present invention, the Fe-based zeolite is used for the second SCR. Consequently, in this aspect of the present invention, the NOx selective reduction performance in the second SCR can be effectively enhanced.

In the seventh aspect of the present invention, the amount of NH_3 stored in the second NOx selective catalytic reduction (second SCR) disposed downstream of the SCR is estimated. The rich spike is then terminated at a timing when the estimated amount is the predetermined amount. Consequently, in this aspect of the present invention, NH_3 can be effectively stored also in the second SCR, so that NOx purifying capacity can be effectively enhanced.

In the eighth aspect of the present invention, the Fe-based zeolite catalyst is used for the SCR and the second SCR. Consequently, in this aspect of the present invention, the NOx selective reduction performance in the SCR and the second SCR can be effectively enhanced.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram for illustrating arrangements of a first embodiment of the present invention.

FIG. **2** is a graph showing changes with time in NOx concentration on a downstream side of an NSR catalyst **16**.

FIG. **3** is a diagram for illustrating a desorption phenomenon of a stored NOx when rich spike is performed.

FIG. **4** is a graph showing an amount of NOx discharged downstream of an SCR **18** and downstream of the NSR catalyst **16**.

FIGS. **5**(A) and **5**(B) are diagrams for illustrating a rich spike control performed in the first embodiment of the present invention.

FIG. **6** is a flow chart showing a routine performed in the first embodiment of the present invention.

FIG. **7** is a flow chart showing a routine performed in the first embodiment of the present invention.

FIG. **8** is a flow chart showing a routine performed in the first embodiment of the present invention.

FIG. **9** is a diagram for illustrating arrangements of a second embodiment of the present invention.

FIG. **10** is a map showing a relationship between an exhaust air-fuel ratio and an NH_3 concentration.

FIG. **11** is a flow chart showing a routine performed in a third embodiment of the present invention.

FIG. **12** is a flow chart showing a routine performed in the third embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Specific embodiments to which the present invention is applied will be described below with reference to the accompanying drawings. Like or corresponding parts are identified by the same reference numerals in all drawings and descriptions for those parts will be omitted. It is further to be understood that the exemplary embodiments to be described hereunder do not limit the scope of the present invention.

First Embodiment

Arrangements of the First Embodiment

FIG. **1** is a diagram for illustrating arrangements of a first embodiment of the present invention. Referring to FIG. **1**, a system according to the embodiment of the present invention includes an internal combustion engine (engine) **10**. An exhaust passage **12** communicates with an exhaust side of the internal combustion engine **10**. A start catalyst (hereinafter referred to as an "SC") **14** as a three-way catalyst is disposed on the exhaust passage **12**. An NSR catalyst (NOx storage-reduction catalyst) **16** is disposed downstream of the SC **14** in the exhaust passage **12**. Further, a NOx selective catalytic reduction (hereinafter referred to an "SCR") **18** is disposed downstream of the NSR catalyst **16** in the exhaust passage **12**.

The internal combustion engine **10** tends to discharge HC and CO when an air-fuel ratio is rich, and tends to discharge NOx when the air-fuel ratio is lean. In a lean environment, the SC **14** reduces NOx (to N_2), while adsorbing oxygen (O_2). In a rich environment, on the other hand, HC and CO are respectively oxidized to H_2O and CO_2, while oxygen is being released. In addition, under the rich environment, nitrogen and hydrogen contained in an exhaust gas react with each other to produce ammonia (NH_3).

The NSR catalyst **16** stores NOx contained in the exhaust gas under the lean environment. In addition, the NSR catalyst **16** releases the stored NOx under the rich environment. The NOx released under the rich environment is reduced by HC or CO. At this time, NH_3 is produced also in the NSR catalyst **16**, as with the SC **14**.

The SCR **18** stores NH_3 produced under the rich environment by the SC **14** and the NSR catalyst **16** and, under the lean environment, selectively reduces NOx in the exhaust gas by using NH_3 as a reducing agent. The SCR **18** can effectively prevent a situation, in which NH_3 and NOx that have leaked downstream of the NSR catalyst **16** are released to the atmosphere, from occurring.

The system shown in FIG. **1** includes an air-fuel ratio (A/F) sensor **20** disposed upstream of the SC **14** in the exhaust passage **12**. The A/F sensor **20** can detect an exhaust air-fuel ratio of the internal combustion engine **10**. The system shown in FIG. **1** further includes oxygen (O_2) sensor **22** disposed upstream of the NSR catalyst **16** and downstream of the SC **14**, and oxygen sensor **24** disposed downstream of the NSR catalyst **16** and upstream of the SCR **18**, in the exhaust passage **12**. The O_2 sensors **22**, **24** generate a signal corresponding to oxygen concentration in the exhaust gas. In addition, a NOx sensor **26** is disposed downstream of the SCR **18** in the exhaust passage **12**. The NOx sensor responds to NOx and NH_3 in the exhaust gas and thereby generates signals corresponding to concentration thereof. The NOx sensor **26** can therefore detect NH_3 concentration under the rich environment and NOx concentration under the lean environment, respectively, on the downstream side of the SCR **18**.

The system shown in FIG. **1** includes, as shown in FIG. **1**, an ECU (electronic control unit) **30**. Actuators of various types including a fuel injection device (not shown) are connected to an output section of the ECU **30**. The A/F sensor **20**, the O_2 sensors **22** and **24**, and the NOx sensor **26** mentioned earlier, and various types of other sensors for detecting operating conditions and states of the internal combustion engine **10** are connected to an input section of the ECU **30**. The ECU **30** can control states of the system shown in FIG. **1** based on inputted various information.

Operation of the First Embodiment

Rich Spike Control

A basic operation of a rich spike control will be described below with reference to FIGS. **2** and **3**. The ECU **30** normally operates the internal combustion engine **10** at a lean air-fuel ratio (a lean operation). During the lean operation, oxidizing agents such as NOx are discharged more than reducing agents such as HC and CO. Accordingly, use of the three-way catalyst for purifying the exhaust gas is not effective in purifying NOx completely due to the insufficient amount of the reducing agents. The system of the first embodiment therefore includes the NSR catalyst **16** in the exhaust passage **12**. The NSR catalyst **16** has a function of storing NOx as nitrate salt such as $Ba(NO_3)_2$. The system of the first embodiment can therefore effectively inhibit a situation, in which the NOx is released into the atmosphere, even during the lean operation.

The NOx storage performance of the NSR catalyst **16** is, however, degraded as a storage amount increases. If the lean operation is run for a long time, therefore, part of NOx that has not been stored leaks downstream of the catalyst. FIG. **2** is a graph showing changes with time in NOx concentration on the downstream side of the NSR catalyst **16**. As shown in this figure, amount of blow-by of Nox that has not been stored by the NSR catalyst **16** gradually increases during the lean operation, due to the NOx storage performance being degraded.

The system of the first embodiment therefore performs the rich spike control in which NOx stored in the NSR catalyst **16** is desorbed at regular intervals. More specifically, referring to FIG. **2**, the exhaust air-fuel ratio of the internal combustion engine **10** is temporarily made rich (e.g. A/F=12) at a predetermined timing when the storage performance of the NSR catalyst **16** is degraded.

FIG. **3** is a diagram for illustrating a desorption phenomenon of the stored NOx when the rich spike is performed. As shown in this figure, the exhaust gas during the performance of the rich spike contains a large amount of reducing agents such as HC, CO, and H_2. Consequently, when these reducing agents are introduced into the NSR catalyst **16**, the NOx stored as the nitrate salt is reduced to NO and desorbed from a base. The desorbed NOx is purified on the catalyst within the NSR catalyst **16** to, for example, N_2. As described above, the performance of the rich spike during the lean operation allows NOx stored in the NSR catalyst **16** to be desorbed, so that the NOx storage performance can be effectively recovered.

(Function and Operation of the SCR **18**)

As described above, the NOx storage performance of the NSR catalyst **16** can be effectively recovered by the performance of the rich spike. Referring to FIG. **2**, however, there exists NOx that leaks downstream of the NSR catalyst **16** during the performance of the rich spike. This represents NOx that, after having been desorbed from the NSR catalyst **16**, is left unpurified on the catalyst and leaks downstream of the catalyst as is. In addition, there also exists, as described earlier, NOx that leaks downstream of the NSR catalyst **16** before the performance of the rich spike. If the blow-by of NOx of these kinds is released into the atmosphere as is, aggravation of emissions is invited.

The system of the first embodiment is therefore adapted to include the SCR **18** that treats NOx that has leaked downstream of the NSR catalyst **16**. As described earlier, the SCR **18** stores thereinside NH_3 produced under the rich environment by the SC **14** and the NSR catalyst **16**. The SCR **18** can therefore selectively reduce and purify NOx that has leaked downstream of the NSR catalyst **16** by using NH_3, thereby effectively inhibiting such a situation as the emissions are aggravated due to release of NOx into the atmosphere.

Various types of materials may be used for the SCR **18**. The inventor of this application has therefore studied SCR materials that can efficiently store NH_3. FIG. **4** is a graph showing an amount of NOx discharged downstream of the SCR **18** and downstream of the NSR catalyst **16**. Note that Ag-based zeolite is used for the SCR **18**. As shown in this figure, the amount of NOx discharged downstream of the SCR **18** increases sharply during the lean operation after the rich spike. From a point of view by the inventor of the application, a reversible reaction shown below probably occurs in the SCR **18**, so that the stored NH_3 is reversed to NOx again.

$$NH_3+O_2 \rightarrow NOx \quad (1)$$

As a result of studies conducted by preparing various types of materials, the inventor of the application has found that the abovementioned reversible reaction is less likely to occur with the SCR **18** using Fe-based zeolite. The system of the first embodiment accordingly uses the SCR **18** using the Fe-based zeolite. This inhibits the abovementioned reversible reaction from occurring, so that the SCR **18** can store NH_3 well.

Researches made by the inventor of the application into reduction performance of the SCR **18** at various floor temperatures have revealed that a reduction reaction in the SCR **18** actively takes place with a floor temperature of the SCR **18** at 500° C. or less, preferably, at around 300° C. In the system of the first embodiment, therefore, the SCR **18** is appropriately disposed such that the floor temperature of the SCR **18** is around 300° C. This effectively inhibits a situation, in which NOx is released downstream of the SCR **18**, from occurring.

Characteristic Operations of the First Embodiment

Characteristic operations of the first embodiment will be described below with reference to FIGS. **5**(A) and **5**(B), or FIG. **6**. As described earlier, NH_3 is produced in the SC **14** and the NSR catalyst **16** (particularly, in the NSR catalyst **16**) under the rich environment, specifically, during the performance of the rich spike. The produced NH_3 is introduced to the SCR **18** disposed downstream of the NSR catalyst **16** and stored thereinside. The stored NH_3 is used for selectively reducing NOx that has leaked downstream of the NSR catalyst **16**. Preferably, therefore, the SCR **18** stores therein a necessary and sufficient amount of NH_3. Making a period of time through which the rich spike is to be performed blindly long, however, poses a problem of aggravated emissions or fuel efficiency.

In order to achieve both storage of NH_3 in the SCR **18** and inhibition of aggravated emissions, the system of the first embodiment controls the air-fuel ratio and a timing of the rich spike according to the operating state of the internal combustion engine **10**. FIGS. **5**(A) and **5**(B) are diagrams for illustrating the rich spike control performed in the first embodiment of the present invention. FIG. **5**(A) shows the control performed when the internal combustion engine **10** runs at light load. FIG. **5**(B) shows the control performed when the internal combustion engine **10** runs at heavy load.

The rich spike control, when the internal combustion engine **10** runs at light load, will first be described. When the internal combustion engine **10** runs at light load, the amount of NOx contained in the exhaust gas is relatively small. Thus, only a slight amount of NOx flows up to the SCR **18** without being stored in the NSR catalyst **16**, so that it is assumed that the amount of NH_3 consumed in the SCR **18** is not so much.

When the internal combustion engine **10** runs at light load, a rich spike as shown in FIG. **5**(A) is therefore performed. Specifically, the rich spike is terminated at a timing of change of an output from the NOx sensor **26**. As described earlier, the NOx sensor **26** responds to NOx and NH_3. Undeniably, the exhaust air-fuel ratio is rich during the performance of the rich spike, so that NOx in the exhaust gas is purified by a three-way catalytic function of the SC **14** and the NSR catalyst **16**. Consequently, when the NOx sensor **26** changes the output state therefrom during the performance of the rich spike, it means that not NOx but NH_3 has leaked downstream of the SCR **18**. The blow-by of NH_3 means that the SCR **18** has adsorbed NH_3 to the full capacity thereof. By terminating the rich spike at the timing of change of the output from the NOx sensor **26**, therefore, the rich spike can be inhibited from being excessively performed, while a maximum amount of NH_3 to be adsorbed by the SCR **18** is ensured.

Referring again to FIG. **5**(A), when the engine runs at light load, the rich spike control varies the rich spike air-fuel ratio in a stepwise fashion. More specifically, after a first-step rich spike (e.g. A/F=12) is performed, a second-step rich spike with an air-fuel ratio leaner than the first-step rich spike (e.g. A/F=14) is performed. This is done to avoid aggravation of CO and HC emissions or fuel efficiency as otherwise caused by continued performance of a fuel-rich rich spike. The first-step rich spike is switched to the second-step rich spike at a timing of change of the output from the O_2 sensor **22**. This results in the second-step rich spike being mainly introduced to the NSR catalyst **16**, so that NH_3 can be stored in the SCR **18**, while aggravation of emissions caused by blow-by of HC or CO is preferentially inhibited.

The rich spike control, when the internal combustion engine **10** runs at heavy load, will next be described. When the internal combustion engine **10** runs at heavy load, the amount

of NOx contained in the exhaust gas is relatively large. Thus, a relatively large amount of blow-by of NOx leaks up to the SCR **18** without being stored in the NSR catalyst **16**, so that it is assumed that a large amount of NH_3 is consumed in the SCR **18**.

Specifically, when the internal combustion engine **10** runs at heavy load, it is required that a large amount of NH_3 be produced during the performance of the rich spike to thereby achieve efficient storage. The inventors of the application have investigated into a relationship between the rich spike and the amount of NH_3 produced and found that a greater amount of NH_3 is produced in the SC **14** and the NSR **16** (particularly, in the NSR **16**) in a short and rich rich spike than in a long and lean rich spike even with the same amount of rich spike.

By using the above characteristic, when the internal combustion engine **10** runs at heavy load, the first-step rich spike is performed for a period of time longer than that when the engine runs at light load. More specifically, as shown in FIG. **5**(B), the first-step rich spike is switched to the second-step rich spike at a timing of change of the output from the O_2 sensor **24**. This ensures that the first-step rich spike continues until the exhaust air-fuel ratio on the downstream side of the NSR catalyst **16** changes from lean to rich, so that the exhaust gas mainly from the first-step rich spike can be introduced into the NSR catalyst **16**. This allows a large amount of NH_3 to be produced, so that the SCR **18** can store therein a large amount of NH_3.

Additionally, when the internal combustion engine **10** runs at heavy load, the rich spike is terminated at the timing of change of the output from the NOx sensor as with the case where the engine runs at light load described above. Thus, the rich spike can be inhibited from being excessively performed, while a maximum amount of NH_3 to be adsorbed by the SCR **18** is ensured.

Specific Operations in the First Embodiment

Specific operations performed in this embodiment will be described below with reference to FIG. **6**. FIG. **6** is a flow chart showing a routine through which the ECU **30** performs the rich spike. FIG. **7** is a flow chart showing a routine of rich spike control I performed in step **104** of FIG. **6**. Further, FIG. **8** is a flow chart showing a routine of rich spike control II performed in step **106** of FIG. **6**. Note that the routine shown in FIG. **6** is to be performed repeatedly during the lean operation of the internal combustion engine **10**.

In the routine shown in FIG. **6**, it is first determined whether or not a condition for performing the rich spike is met (step **100**). Specifically, it is herein determined whether or not a predetermined period of time elapses since the performance of a preceding rich spike control. When, as a result, it is determined that the condition for performing the rich spike is not met, this routine is quickly terminated.

When it is determined in step **100**, on the other hand, that the condition for performing the rich spike is met, the operation proceeds to a subsequent step and it is determined whether or not the internal combustion engine **10** runs at light load (step **102**). Specifically, herein, an engine load KL is first calculated based on detection signals by the various sensors that detect the operating state of the internal combustion engine **10**. It is then determined whether or not the engine load KL is smaller than a predetermined reference value KL_t (e.g. KL_t=50).

When it is determined in step **102** that KL<KL_t holds true, it is then determined that the internal combustion engine **10** runs at predetermined light load. The operation then proceeds to a subsequent step and rich spike control I is performed (step **104**). In step **104**, the routine shown in FIG. **7** is started.

In the routine shown in FIG. **7**, the first-step rich spike control is first performed (step **110**). Specifically, the fuel injection device is herein controlled such that the exhaust air-fuel ratio of the internal combustion engine **10** is a predetermined rich air-fuel ratio (e.g. A/F=12). It is then determined whether or not the O_2 sensor **22** changes the output state therefrom (step **112**). When it is determined, as a result, that the O_2 sensor **22** does not change the output state therefrom, it is determined that the air-fuel ratio on the upstream side of the NSR catalyst **16** is still lean, and the operation of this step is repeatedly performed.

When it is determined in step **112**, on the other hand, that the O_2 sensor **22** changes the state therefrom, it is determined that the air-fuel ratio on the upstream side of the NSR catalyst **16** changes from lean to rich. The operation proceeds to a subsequent step and the second-step rich spike controll is performed (step **114**). Specifically, the rich spike exhaust air-fuel ratio is herein changed to one leaner than that of the first-step rich spike (e.g. A/F=14).

In the routine shown in FIG. **7**, it is next determined whether or not the NOx sensor **26** changes the output state therefrom (step **116**). When it is determined, as a result, that the NOx sensor **26** does not change the output state therefrom, it is determined that NH_3 is yet to leak downstream of the SCR **18**, and the operation of this step is repeatedly performed.

When it is determined, on the other hand, that the NOx sensor **26** changes the output state therefrom, it is determined that NH_3 that has not been stored leaks downstream of the SCR **18**. The operation proceeds to a subsequent step and the rich spike control is terminated (step **118**). Specifically, the air-fuel ratio of the internal combustion engine **10** is herein controlled to that of an ordinary lean operation. The routine shown in FIG. **7** is then terminated.

When it is determined, on the other hand, in step **102** of the routine shown in FIG. **6** that KL<KL_t does not hold true, it is determined that the internal combustion engine **10** runs at predetermined heavy load. The operation then proceeds to a subsequent step and rich spike control II is performed (step **106**). In step **106**, the routine shown in FIG. **8** is started.

In the routine shown in FIG. **8**, the first-step rich spike control is first performed (step **120**). Specifically, the same operation as that in step **110** is herein performed. It is then determined whether or not the O_2 sensor **24** changes the output state therefrom (step **122**). When it is determined, as a result, that the O_2 sensor **24** does not change the output state therefrom, it is determined that the air-fuel ratio on the downstream side of the NSR catalyst **16** is still lean and the operation of this step is repeatedly performed.

When it is determined in step **122**, on the other hand, that the O_2 sensor **24** changes the output state therefrom, it is determined that the air-fuel ratio on the downstream side of the NSR catalyst **16** changes from lean to rich. The operation proceeds to a subsequent step, and the second-step rich spike is performed (step **124**). It is next determined whether or not the NOx sensor **26** changes the output state therefrom (step **126**). Specifically, the same operations as those in steps of from steps **114** to **116** are herein performed. When it is determined, as a result, that the NOx sensor **26** does not change the output state therefrom, it is determined that NH_3 is yet to leak downstream of the SCR **18**, and the operation of this step is repeatedly performed.

When it is determined in step **126**, on the other hand, that the NOx sensor **26** changes the output state therefrom, it is determined that NH_3 that has not been stored leaks downstream of the SCR **18**. The operation proceeds to a subsequent

step and the rich spike control is terminated (step **128**). Specifically, the same operation as that in step **118** is herein performed. The routine shown in FIG. **8** is then terminated.

As described heretofore, in the system of the first embodiment, the rich spike is terminated at the timing of change of the output state from the NOx sensor **26**. This ensures that a maximum amount of NH_3 can be stored in the SCR **18** and the rich spike can be inhibited from being excessively performed.

Additionally, in the system of the first embodiment, the rich spike air-fuel ratio is switched from the first step to the second step at the timing of change of the output from the O_2 sensor **22**, when the internal combustion engine **10** runs at light load. This inhibits a situation in which the first-step rich spike is introduced to the NSR catalyst **16**, thereby effectively inhibiting such a situation as the emissions are aggravated due to CO or HC leakage downstream of the NSR catalyst **16**.

Additionally, in the system of the first embodiment, the rich spike air-fuel ratio is switched from the first step to the second step at the timing of change of the output from the O_2 sensor **24**, when the internal combustion engine **10** runs at heavy load. This allows a large amount of NH_3 to be produced in the NSR catalyst **16**, so that a large amount of NH_3 can be efficiently stored in the SCR **18**.

In the above-described first embodiment, the rich spike is terminated at the timing of change of the output from the NOx sensor **26**. This timing is not, however, limited only to the case in which the output state is changed. Specifically, any other timing may be employed as long as an output characteristic signal indicating that NH_3 has leaked downstream of the SCR **18** is developed at such a timing during the performance of the rich spike. In addition, the timing of switching the first-step rich spike control to the second-step rich spike control is not limited only to the case in which the output states of the O_2 sensors **22** and **24** are changed. Specifically, any other timing may be employed as long as an output characteristic signal indicating that the air-fuel ratio becomes rich is developed at such a timing during the performance of the rich spike.

Note that, in the above-described first embodiment, the NSR catalyst **16** corresponds to the "NSR catalyst" in the first aspect of the present invention, the SCR **18** corresponds to the "SCR" in the first aspect of the present invention, and the NOx sensor **26** corresponds to the "exhaust gas sensor" in the first aspect of the present invention. In addition, in the above-described first embodiment, the ECU **30** performs the operation of step **104** or **106**, thereby achieving the "rich spike means" in the first aspect of the present invention.

Additionally, in the above-described first embodiment, the SC **14** corresponds to the "three-way catalyst" in the second aspect of the present invention, and the O_2 sensor **22** corresponds to the "second exhaust gas sensor" in the second aspect of the present invention. In addition, in the above-described first embodiment, the ECU **30** performs: the operation of step **110**, thereby achieving the "first rich spike means" in the second aspect of the present invention; the operation of step **114**, thereby achieving the "second rich spike means" in the second aspect of the present invention; and the operation of step **112**, thereby achieving the "switchover means" in the second aspect of the present invention.

Additionally, in the above-described first embodiment, the O_2 sensor **24** corresponds to the "third exhaust gas sensor" in the third aspect of the present invention. Further, the ECU **30** performs: the operation of step **120**, thereby achieving the "first rich spike means" in the third aspect of the present invention; the operation of step **124**, thereby achieving the "second rich spike means" in the third aspect of the present invention; and the operation of step **122**, thereby achieving the "switchover means" in the third aspect of the present invention.

Second Embodiment

Characteristics of the Second Embodiment

A second embodiment of the present invention will be described below with reference to FIG. **9**. FIG. **9** is a diagram for illustrating arrangements of the second embodiment of the present invention. In a system shown in FIG. **9**, like or corresponding parts are identified by the same reference numerals as those used for the first embodiment of the present invention and descriptions for those parts will be omitted.

Referring to FIG. **9**, the system of this embodiment includes another SCR **28** on a downstream side of a NOx sensor **26** in an exhaust passage **12**. The SCR **28** uses the Fe-based zeolite as with the SCR **18**. In addition, the SCR **28** is formed to have a smaller capacity than the SCR **18** does.

In the above-described first embodiment, the rich spike is terminated at the timing of change of the output from the NOx sensor **26**. A maximum amount of NH_3 can thereby be stored in the SCR **18** and the rich spike can thereby be inhibited from being excessively performed. Even if the rich spike is terminated at such a timing, however, NH_3 that represents a portion of transport lag thereafter leaks through the SCR **18** and is released into the atmosphere.

In this respect, in the system of the second embodiment, the SCR **28** traps the NH_3 representing the transport lag portion that has leaked through the SCR **18**, thereby effectively inhibiting a situation in which the NH_3 representing the transport lag portion is released into the atmosphere immediately after the end of the rich spike.

In the above-described second embodiment, the SCR **28** corresponds to the "second SCR" in the fifth aspect of the present invention.

Third Embodiment

Characteristics of the Third Embodiment

A third embodiment of the present invention will be described below with reference to FIGS. **10** to **12**. The third embodiment is achieved by use of the system shown in FIG. **9** that performs routine shown in FIG. **11** in rich spike control I shown in FIG. **6** and routine shown in FIG. **12** in rich spike control II shown in FIG. **6**.

As described earlier, a large amount of NOx is discharged when the internal combustion engine **10** runs at heavy load. Thus, NOx which the NSR **16** fails to treat leaks downstream of the catalyst, so that a large amount of NOx may blow into the SCR **18**. It is expected, in this case, that the SCR **18** has an insufficient amount of NH_3 stored therein depending on the capacity thereof.

The above-described system of the second embodiment includes the additional SCR **28** disposed downstream of the SCR **18** as shown in FIG. **9**. The SCR **28** in the system of the second embodiment is used as a buffer for trapping the NH_3 representing the transport lag portion after the rich spike. Consequently, in the system of the second embodiment, the SCR **28** is not actively used as a catalyst for purifying NOx.

A system of the third embodiment therefore lets the SCR **28** actively adsorb NH_3 to use the SCR **28** actively for purifying NOx. More specifically, a rich spike time is extended for a predetermined period of time to thereby allow a predetermined amount of NH_3 to be stored within the range of

capacity of the SCR **28**. This allows NH_3 to be effectively stored in the SCR **28**, while inhibiting NH_3 from being released downstream of the SCR **28**.

In order to allow a predetermined amount of NH_3 to be stored in the SCR **28**, it becomes necessary to identify the amount of NH_3 that blows into the SCR **28**. In the third embodiment, a map shown in FIG. **10** is used to estimate the amount of NH_3 that flows into the SCR **28**. The map shown in FIG. **10** shows a relationship between an exhaust air-fuel ratio and an NH_3 concentration. The map allows the NH_3 concentration to be specifically determined based on the exhaust gas air-fuel ratio. The amount of exhaust gas herein can be calculated based on the engine load KL of the internal combustion engine **10**. Thus, the amount of NH_3 that flows into the SCR **28** can be estimated based on the specifically determined NH_3 concentration and the amount of exhaust gas.

A rich spike extension time T required for the predetermined amount of NH_3 to be stored in the SCR **28** can be calculated based on the estimated amount of NH_3. In the system of the third embodiment, therefore, the rich spike is terminated after the lapse of the extension time T since the introduction of NH_3 into the SCR **28** after changing the output state of the NOx sensor **26** during the performance of the rich spike. This allows the rich spike to be terminated with the predetermined amount of NH_3 stored in the SCR **28**.

Specific Operations in the Third Embodiment

Specific operations to be performed in this embodiment will be described below with reference to FIGS. **11** and **12**. FIG. **11** is a flow chart showing a routine of rich spike control I performed in step **104** of FIG. **6**. FIG. **12** is a flow chart showing a routine of rich spike control II performed in step **106** of FIG. **6**. The routine shown in FIG. **6** has been described with reference to the first embodiment and will thus be omitted.

When the operation proceeds to step **104** in the routine shown in FIG. **6**, the routine shown in FIG. **11** is started. In the routine shown in FIG. **11**, the first-step rich spike control is first performed (step **200**). It is next determined whether or not the output state of the O_2 sensor **22** is changed (step **202**). Specifically, the same operations as in steps of from steps **110** to **112** are herein performed. When it is determined, as a result, that the output state of the O_2 sensor **22** is not changed, the operation of this step is repeatedly performed. When it is determined in step **202**, on the other hand, that the output state of the O_2 sensor **22** is changed, the second-step rich spike control is performed (step **204**). It is then determined whether or not the output state of the NOx sensor **26** is changed (step **206**). Specifically, the same operations as in steps of from steps **114** to **116** are herein performed. When it is determined, as a result, that the output state of the NOx sensor **26** is not changed, it is determined that NH_3 is yet to leak downstream of the SCR **18** and the operation of this step is repeatedly performed.

When it is determined in step **206**, on the other hand, that the output state of the NOx sensor **26** is changed, it is determined that NH_3 that has not been stored leaks downstream of the SCR **18**. The operation proceeds to a subsequent step and the rich spike extension time T is calculated (step **208**). Specifically, the concentration of NH_3 is herein first calculated. The ECU **30** stores in memory the map shown in FIG. **10**. Herein, the concentration of NH_3 corresponding to the exhaust air-fuel ratio is identified in accordance with the map. Next, a flow rate of the exhaust gas is calculated based on the engine load of the internal combustion engine **10**. Then, based on the NH_3 concentration and the exhaust gas flow rate thus obtained, the amount of NH_3 flowing into the SCR **28** is calculated. Next, based on the amount of NH_3 flowing into the SCR **28**, the rich spike extension time T required for the predetermined amount of NH_3 to be stored is calculated.

Next, it is determined whether or not the rich spike extension time T elapses (step **210**). Herein, it is determined whether or not the extension time T calculated in step **208** elapses since it is determined in step **206** that the output state of the NOx sensor **26** is changed. When it is determined, as a result, that the extension time T is yet to elapse, this step is repeatedly performed.

When, on the other hand, it is determined in step **210** that the rich spike extension time T elapses, the operation proceeds to a subsequent step and the rich spike control is terminated (step **212**) to complete the routine shown in FIG. **11**.

When, on the other hand, the operation proceeds to step **106** in the routine shown in FIG. **6**, the routine shown in FIG. **12** is started. In the routine shown in FIG. **12**, the first-step rich spike control is first performed (step **220**). It is next determined whether or not the output state of the O_2 sensor **24** is changed (step **222**). Specifically, the same operations as in steps of from steps **120** to **122** are herein performed. When it is determined, as a result, that the output state of the O_2 sensor **24** is not changed, the operation of this step is repeatedly performed. When it is determined in step **222**, on the other hand, that the output state of the O_2 sensor **24** is changed, the second-step rich spike control is performed (step **224**). It is then determined whether or not the output state of the NOx sensor **26** is changed (step **226**). Specifically, the same operations as in steps of from steps **124** to **126** are herein performed. When it is determined, as a result, that the output state of the NOx sensor **26** is not changed, it is determined that NH_3 is yet to leak downstream of the SCR **18** and the operation of this step is repeatedly performed.

When it is determined in step **226**, on the other hand, that the output state of the NOx sensor **26** is changed, it is determined that NH_3 that has not been stored leaks downstream of the SCR **18**. The operation proceeds to a subsequent step and the rich spike extension time T is calculated (step **228**). Specifically, the same operation as in step **208** is herein performed. It is next determined whether or not the rich spike extension time T elapses (step **230**). Specifically, the same operation as in step **210** is herein performed. When, as a result, the extension time T is yet to elapse, this step is repeatedly performed.

When it is determined in step **220**, on the other hand, that the rich spike extension time T elapses, the operation proceeds to a subsequent step and the rich spike control is terminated (step **232**) to complete the routine shown in FIG. **12**.

As described heretofore, in the system of the third embodiment, the timing of termination of the rich spike is extended, so that the predetermined amount of NH_3 can be stored in the SCR **28**. This allows a total amount of NH_3 stored in the SCR **18** and the SCR **28** to be effectively increased, so that a situation in which NOx that is yet to be purified is released into the atmosphere can be effectively inhibited even if a large amount of NOx is discharged.

Additionally, in the system of the third embodiment, NH_3 is stored in the SCR **28** within the range of capacity of the SCR **28**, thereby effectively inhibiting a situation in which NH_3 that the SCR **28** fails to store leaks downstream.

In the above-described the third embodiment, the NH_3 concentration is identified in accordance with the map specified in FIG. **10** and the amount of NH_3 to be stored in the SCR **28** is estimated by using the identified NH_3 concentration. This is, however, not the only possible method for estimating the amount of NH_3. Specifically, a sensor that can detect the

NH_3 concentration may be disposed downstream of the NSR catalyst **16** and the sensor is used to directly detect the amount of NH_3 for estimating the amount of NH_3. Alternatively, other well-known techniques may be employed to estimate the amount of NH_3 stored in the SCR **28**.

In the above-described third embodiment, the NSR catalyst **16** corresponds to the "NSR catalyst" in the seventh aspect of the present invention, the SCR **18** corresponds to the "SCR" in the seventh aspect of the present invention, and the SCR **28** corresponds to the "second SCR" in the seventh aspect of the present invention. In addition, in the above-described third embodiment, the ECU **30** performs: the operation of step **104** or **106**, thereby achieving the "rich spike means" in the seventh aspect of the present invention; and the operation of step **208**, thereby achieving the "estimating means" in the seventh aspect of the present invention.

DESCRIPTION OF REFERENCE CHARACTERS

10: internal combustion engine (engine)
12: exhaust passage
14: start catalyst (SC)
16: NOx storage-reduction catalyst (NSR catalyst)
18: NOx selective catalytic reduction (SCR)
20: A/F sensor
22: O_2 sensor
24: O_2 sensor
26: NOx sensor
28: NOx selective catalytic reduction (SCR)
30: ECU (electronic control unit)

The invention claimed is:

1. An exhaust purifying system for an internal combustion engine capable of a lean burn operation, the exhaust purifying system comprising:

an NOx storage-reduction catalyst (hereinafter referred to as an "NSR catalyst") disposed in an exhaust passage of the internal combustion engine;

an NOx selective catalytic reduction (hereinafter referred to as an "SCR") disposed downstream of the NSR catalyst;

an exhaust gas sensor disposed downstream of the SCR, the exhaust gas sensor producing an output according to an NH_3 concentration;

an electric control unit programmed to perform a rich spike, wherein the electric control unit is further programmed to start the rich spike at a predetermined timing during a lean burn operation and terminates the rich spike at a timing when the exhaust gas sensor issues a predetermined output characteristic indicative of a rise in the NH_3 concentration;

a second exhaust gas sensor disposed downstream of the NSR catalyst and upstream of the SCR, the second exhaust gas sensor producing an output according to the oxygen concentration,

wherein the electric control unit is further programmed to:

perform a first rich spike at a predetermined air-fuel ratio;

perform a second rich spike at an air-fuel ratio leaner than the predetermined air-fuel ratio; and

switch operation mode from the first rich spike to the second rich spike at a timing when the second exhaust gas sensor issues a predetermined output characteristic indicative of a reduction in the oxygen concentration when the internal combustion engine runs at heavy load.

2. The exhaust purifying system for an internal combustion engine according to claim **1**, wherein

the SCR is an Fe-based zeolite catalyst.

3. The exhaust purifying system for an internal combustion engine according to claim **1**, further comprising:

a second NOx selective catalytic reduction (hereinafter referred to as a "second SCR") disposed downstream of the exhaust gas sensor.

4. The exhaust purifying system for an internal combustion engine according to claim **3**, wherein

the second SCR is an Fe-based zeolite catalyst.

5. An exhaust purifying system for an internal combustion engine capable of a lean burn operation, the exhaust purifying system comprising:

an NOx storage-reduction catalyst (hereinafter referred to as an "NSR catalyst") disposed in an exhaust passage of the internal combustion engine;

an NOx selective catalytic reduction (hereinafter referred to as an "SCR") disposed downstream of the NSR catalyst;

an exhaust gas sensor disposed downstream of the SCR, the exhaust gas sensor producing an output according to an NH_3 concentration;

an electric control unit programmed to perform a rich spike, wherein the electric control unit is further programmed to start the rich spike at a predetermined timing during a lean burn operation and terminates the rich spike at a timing when the exhaust gas sensor issues a predetermined output characteristic indicative of a rise in the NH_3 concentration;

a three-way catalyst disposed upstream of the NSR catalyst; and

a second exhaust gas sensor disposed upstream of the NSR catalyst and downstream of the three-way catalyst, the second exhaust gas sensor producing an output according to an oxygen concentration:

wherein the electric control unit is further programmed to:

perform a first rich spike at a predetermined air-fuel ratio;

perform a second rich spike at an air-fuel ratio leaner than the predetermined air-fuel ratio; and

switch operation mode from the first rich spike to the second rich spike at a timing when the second exhaust gas sensor issues a predetermined output characteristic indicative of a reduction in the oxygen concentration when the internal combustion engine runs at light load.

6. The exhaust purifying system for an internal combustion engine according to claim **5**, wherein

the SCR is an Fe-based zeolite catalyst.

7. The exhaust purifying system for an internal combustion engine according to claim **5**, further comprising:

a second NOx selective catalytic reduction (hereinafter referred to as a "second SCR") disposed downstream of the exhaust gas sensor.

8. The exhaust purifying system for an internal combustion engine according to claim **7**, wherein

the second SCR is an Fe-based zeolite catalyst.

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